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Comparison of perioperative and mid-term outcomes between laparoscopic and robotic inguinal hernia repair

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Abstract

Background Although the advantages of laparoscopic inguinal hernia repair (LIHR) have been described, guidelines regarding robotic inguinal hernia repair (RIHR) have yet to be established, despite its increased adoption as a minimally invasive alternative. This study compares the largest single-center cohorts of LIHR and RIHR and aims to shed light on the differences in outcomes between these two techniques.

Methods Patients who underwent LIHR or RIHR over an 8-year period were included as part of a retrospective analysis. Variables were stratified by preoperative, intraoperative, and postoperative timeframes. Complications were listed according to the Clavien–Dindo classification system and comprehensive complication index (CCI®). Study groups were compared using univariate analyses and Kaplan–Meier's time-to-event analysis.

Results A total of 1153 patients were included: 606 patients underwent LIHR, while 547 underwent RIHR. Although demographics and comorbidities were mostly similar between the groups, the RIHR group included a higher proportion of complex hernias. Operative times were in favor of LIHR (42 vs. 53 min, $p<0.001$), while RIHR had a smaller number of peritoneal breaches (0.4 vs. 3.8%, $p<0.001$) as well as conversions (0.2 vs. 2.8%, $p<0.001$). The number of patients lost-to-follow-up and the average follow-up times were similar ($p=0.821$ and $p=0.304$, respectively). Postoperatively, CCI® scores did not differ between the two groups (median = 0, $p=0.380$), but Grade IIIB complications (1.2 vs. 3.3%, $p=0.025$) and recurrences (0.8% vs. 2.9%, $p=0.013$) were in favor of RIHR. Furthermore, estimated recurrence-free time was higher in the RIHR group [$p=0.032$; 99.7 months (95% CI 98.8–100.5) vs. 97.6 months (95% CI 95.9–99.3).

Conclusion This study demonstrated that RIHR may confer advantages over LIHR in terms of addressing more complex repairs while simultaneously reducing conversion and recurrence rates, at the expense of prolonged operation times. Further large-scale prospective studies and trials are needed to validate these findings and better understand whether RIHR offers substantial clinical benefit compared with LIHR.

Keywords Laparoscopic · Robotic · Minimally invasive · Inguinal hernia · Groin hernia

Although open mesh repair remains the predominant treatment modality for inguinal hernia, there is an undeniable rising interest in the adoption of minimally invasive alternatives. A review of literature justifies this trend, with several impactful studies showing benefits to laparoscopic inguinal hernia repair (LIHR) over open inguinal hernia repair (OIHR), including chronic pain, return to activity, wound infection, and overall cost effectiveness [1–3]. Analogous advantages have been reported with emerging robotic inguinal hernia repair (RIHR). However, there are little data to support its selection when compared to LIHR. Despite concerns over operative time, cost, and a lack of established superiority over LIHR, the rate of RIHR has increased tremendously from 0.08% in 2010 to 3.27% in 2015, with an adjusted odds ratio for an RIHR being performed in 2011 of 1.19 versus 49.38 in 2015 [4]. This study contributes a single-center, multi-surgeon experience over 8 years that compares LIHR and RIHR, aiming to highlight factors that may influence the choice of one approach over the other.

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Materials and methods

Study data involving patients undergoing minimally invasive IHR between January 2012 and August 2020 were collected and managed using the research electronic data capture (REDCap) tool [5]. All procedures took place at a single hospital and were performed by four surgeons. Patients who underwent a concomitant procedure outside of the index IHR were excluded. The remaining patients were divided into two groups based on surgical approach: laparoscopic and robotic. Preoperative, intraoperative, and postoperative variables were compared.

The variables included patients' age, sex, body mass index [BMI], comorbidities, the American Society of Anesthesiologists [ASA] score, hernia side, complex hernias (i.e., previous posterior repair, previous prostatectomy, incarceration, scrotal) operative details, the type of mesh, mesh dimensions, operative times, estimated blood loss in mL [EBL], intraoperative complications, and postoperative pain scores, the length of hospital stay [LOS], hospital readmission within 30 days after discharge, and complications. Postoperative pain scores were documented according to a 0–10 numeric rating scale system (0: no pain, 10: the worst pain) just before the patient left the post-anesthesia care unit (PACU). The total amount of narcotic analgesic received while in the PACU was also calculated in terms of the morphine milligram equivalent (MME). The LOS, in days, was defined as the difference in time between the date of the operation and the date of hospital discharge. Data on postoperative complications were retrieved from the surgeon's follow-up visit notes, as well as the medical records and clinical charts of the patients. A routine follow-up schedule was implemented consisting of postoperative clinic visits and/or phone calls at 1–3 months, 3–6 months, 6 months to 1 year, and > 1 year. Every patient's last follow-up encounter was used to calculate their total follow-up time. All complications were categorized according to the Clavien–Dindo classification system [6]. The comprehensive complication index (CCI®, University of Zurich, Zurich, Switzerland) was used to assess the morbidity [7].

Surgical technique

Laparoscopic totally extraperitoneal repair (L-TEP)

Following standard preoperative preparation, the patient was placed in supine position and prepped and draped in usual sterile fashion. An infraumbilical transverse skin incision was made and carried down to the posterior rectus sheath, through which a camera trocar was placed. Blunt dissection, via a balloon trocar or camera tip, was then used to dissect the extraperitoneal plane to help insert two additional trocars under direct visualization. Once instruments were introduced, the borders of working space were extended laterally and inferiorly. Anatomical landmarks such as the pubic bone, inferior epigastric vessels, cord structures, and iliac vessels were identified. By dissecting the hernia sac, the contents and associated hernia defects were identified. These steps were repeated for the contralateral side in the case of a bilateral inguinal hernia. Once the hernia was reduced and the inguinal floor was dissected sufficiently, a mesh was deployed over the defect, covering the entire myopectineal orifice (MPO). If required, the mesh was secured in position. The working space was de-sufflated under direct visualization and all trocars were removed. The procedure was finalized by closing fascial and skin incisions.

Robotic transabdominal preperitoneal repair (R-TAPP)

Our surgical technique has previously been described [8]. Following preparation and appropriate trocar placement, the patient-side cart of the da Vinci surgical robotic system (Intuitive Surgical, Sunnyvale, CA) was docked. Peritoneal dissection was initiated 8–10 cm above the internal inguinal ring and was extended inferiorly toward the deep inguinal ring, laterally toward the psoas muscle, and medially at least 2 cm between Cooper's ligament and the bladder to achieve adequate mesh overlap in the space of Retzius. Once proper exposure of Fruchaud's MPO was obtained, the selected mesh was introduced to cover the entire MPO. If required, the mesh was secured in position. The peritoneal flap was then closed using a 3–0 absorbable barbed suture. Skin incisions were closed using absorbable sutures after administration of local anesthetic (1% bupivacaine hydrochloride) at the trocar sites.

Statistical analysis

Categorical variables were presented in terms of frequency [*n* (%)], while continuous variables were reported as the mean ± the standard deviation (SD) for normal distributions or the median with interquartile range (IQR) for non-normal distributions. Categorical variables were analyzed using Pearson Chi-Square or Fisher's Exact Tests. Continuous variables were analyzed using the two-tailed student *t* test (for normal distributions) or Mann–Whitney *U* test (for non-normal distributions). Kaplan–Meier's time-to-event analysis was performed to determine the freedom from recurrence. A *p*-value of less than 0.05 was considered significant. All statistical analyses were performed using SPSS

software (Statistical Package for Social Sciences for Windows Version 22).

Results

A total of 1153 patients who underwent minimally invasive IHRs were identified. From these, 606 patients underwent LIHR, while 547 patients underwent RIHR. All robotic procedures were performed by one surgeon, while laparoscopic repairs were performed by four surgeons. Patient demographics are compared in Table 1. A larger number of patients with an ASA score of I and III were observed in RIHR group. Eighteen (3%) patients underwent LIHR in an urgent/emergent setting versus 19 (3.5%) patients in the RIHR group ($p=0.628$). All patients in the RIHR group and 3 patients in the LIHR group underwent repair with a TAPP technique (TEP for 603 patients in the LIHR group; $p<0.001$). Hernia characteristics are summarized in Table 2. The distribution of bilateral hernias did not differ between LIHR (28.1%) and RIHR (30.2%) groups ($p=0.436$). The distribution of recurrent inguinal hernias was 70 (11.6%) in the LIHR group and 76 (13.9%) in the RIHR group ($p=0.232$). From the recurrent hernias in the LIHR group, 53 (8.7%) were from previous ipsilateral open repairs, as compared to 49 (9%) in the RIHR group ($p=0.899$). There were significantly more complex inguinal hernias in the robotic group (152 vs. 90, $p<0.001$).

A comparison of intraoperative variables is presented in Table 3. Mesh selection was at the surgeon's discretion. Polyester was the predominant choice with RIHR (94.7%) and polypropylene with LIHR (77.9%). Accordingly, mesh fixation methods differed based on surgeon preference and type of mesh. The most prevalent option was no fixation with 94.1% in RIHR versus 67.9% in LIHR. Tack fixation was not implemented in any RIHR procedure compared to 31.1% of LIHR procedures, whereas suture fixation was used in 1% and 5.9% of RIHRs and LIHRs, respectively. On average, a larger mesh size was used in the robotic group. Total operative time was in favor of the LIHR group (42 vs. 53 min, $p<0.001$). Intraoperative complications were seen in 3 (0.5%) patients in both groups; two minor serosal injuries and bleeding in the RIHR group and 2 CO_2 retention and

Table 1 Comparison of patient demographics

	LIHR ($n=606$)	RIHR ($n=547$)	p value
Age, mean ± SD	58.4 ± 15.8	59.3 ± 16	0.372
Sex, male, *n* (%)	568 (93.7)	500 (91.4)	0.132
BMI (kg/m^2), median (IQR)	26.4 (24–29.3)	26.6 (24.2–29.8)	0.307
ASA class, median (IQR)	2 (2–3)	2 (2–3)	**< 0.001**
ASA-I, *n* (%)	93 (15.3)	58 (10.6)	
ASA-II, *n* (%)	355 (25.6)	298 (54.5)	
ASA-III, *n* (%)	155 (25.6)	190 (34.7)	
ASA-IV, *n* (%)	3 (0.5)	1 (0.2)	
Comorbidities			
HT, *n* (%)	250 (41.3)	224 (41)	0.917
CAD, *n* (%)	47 (7.8)	56 (10.2)	0.140
COPD, *n* (%)	35 (5.8)	39 (7.1)	0.349
Smoking, *n* (%)	102 (16.8)	112 (20.5)	0.112
DM, *n* (%)	56 (9.2)	58 (10.6)	0.439

Values in bold represent a p value < 0.05

SD standard deviation, *IQR* interquartile range, *BMI* body mass index, *ASA* the American Society of Anesthesiologists, *HT* hypertension, *CAD* coronary artery disease, *COPD* chronic obstructive pulmonary disease, *DM* diabetes mellitus

Table 2 Comparison of hernia characteristics

	LIHR ($n=606$)	RIHR ($n=547$)	p value
Right-sided hernia, *n* (%)	416 (68.6)	374 (68.4)	0.920
Direct, *n* (%)	114 (18.8)	105 (19.2)	0.868
Indirect, *n* (%)	341 (56.3)	292 (53.4)	0.325
Femoral, *n* (%)	21 (3.5)	11 (2)	0.133
Obturator, *n* (%)	2 (0.3)	0 (0)	0.501
Left sided hernia, *n* (%)	360 (59.4)	338 (61.8)	0.408
Direct, *n* (%)	84 (13.9)	121 (22.1)	**< 0.001**
Indirect, *n* (%)	301 (49.7)	239 (43.7)	**0.042**
Femoral, *n* (%)	12 (2)	5 (0.9)	0.134
Obturator, *n* (%)	1 (0.2)	1 (0.2)	1.000
Complex hernia, *n* (%)	90 (14.9)	152 (27.8)	**< 0.001**
Previous posterior repair, *n* (%)	17 (2.8)	27 (4.9)	0.059
Previous prostatectomy, *n* (%)	14 (2.3)	10 (1.8)	0.567
Incarceration, *n* (%)	50 (8.3)	74 (13.5)	**0.004**
Scrotal, *n* (%)	13 (2.1)	75 (13.7)	**< 0.001**

Values in bold represent a p value < 0.05

Table 3 Comparison of operative variables

	LIHR ($n=606$)	RIHR ($n=547$)	p value
Mesh sizes			
Length, cm, median (IQR)	15.7 (15.7–15.7)	16 (15–16)	**< 0.001**
Width, cm, median (IQR)	10.5 (10.5–10.5)	12 (10–12)	**< 0.001**
Mesh material			
Polypropylene, *n* (%)	480 (79.3)	29 (5.3)	**< 0.001**
Polyester, *n* (%)	122 (20.2)	518 (94.7)	
Absorbable, *n* (%)	3 (0.5)	0 (0)	
Operating time, min, median (IQR)	42 (33–57)	53 (40–76)	**< 0.001**
Estimated blood loss, mL, median (IQR)	5 (5–10)	5 (5–5)	**< 0.001**
Intraoperative complications, *n* (%)	3 (0.5)	3 (0.5)	1.000
Peritoneal breach, *n* (%)	23 (3.8)	2 (0.4)	**< 0.001**
Dividing the epigastric vessels, *n* (%)	6 (1)	1 (0.2)	0.127
Conversion to other approaches	17 (2.8)	1 (0.2)	**< 0.001**
To Open	13 (2.1)	1 (0.2)	
To TAPP	4 (0.7)	N/A	

Values in bold represent a p value < 0.05

IQR interquartile range

bleeding in the LIHR group. The median (IQR) pain score was 3 (1–4) in both groups ($p=0.051$). The median (IQR) MME was 7.5 (0–10) and 7.5 (0–15) in the LIHR group and the RIHR group, respectively ($p=0.789$). There was also no difference in the median (IQR) hospital LOS [0 (0–0) for both groups; $p=0.051$]. 8 (1.3%) patients in the LIHR group and 5 (0.9%) patients in the RIHR group were readmitted to the hospital within a 30-day postoperative period ($p=0.514$).

Sixty (9.9%) patients the LIHR group and 52 (9.5%) patients in the RIHR group were lost to follow-up ($p=0.821$). After excluding patients who were lost to follow-up, the mean (± SD) follow-up time for RIHR and LIHR patients was 42.2 (21.2) months and 43.8 (28.4) months, respectively ($p=0.304$). Postoperative complications are compared in Table 4. Notably, a higher rate of major complications (CD grade III and IV) were observed in the LIHR group (4.9% in LIHR group vs. 2.2% in RIHR group; $p=0.019$]. This higher rate is mostly attributed to CD Grade IIIB complications, the vast majority of which consisted of hernia recurrences; 16 (2.9%) patients in LIHR group versus 4 (0.8%) in RIHR group; $p=0.013$. Furthermore, Kaplan–Meier's time-to-event analysis (Fig. 1) showed that estimated recurrence-free time was higher after RIHR [99.6 months, 95% Confidence Interval (CI) 98.8–100.5] than LIHR (97.6 months, 95% CI 95.9–99.3), (Mantel–Cox Log rank test, $p=0.032$).

Table 4 Comparison of postoperative complications

	LIHR ($n=546$)	RIHR ($n=495$)	p value
Clavien–Dindo classification			
Grade I, *n* (%)	47 (8.6)	54 (10.4)	0.210
Grade II, *n* (%)	10 (1.8)	4 (0.8)	0.152
Grade IIIA, *n* (%)	9 (1.6)	3 (0.6)	0.116
Grade IIIB, *n* (%)	18 (3.3)	5 (1)	**0.012**
Grade IVA, *n* (%)	0 (0)	2 (0.4)	0.226
CCI® score, median (range)	0 (0–33.7)	0 (0–20.9)	0.380
SSEs, *n* (%)			
SSI, *n* (%)	4 (0.7)	2 (0.4)	0.689
SSOs, *n* (%)	28 (5.1)	20 (4)	0.403
Seroma, *n* (%)	14 (2.6)	11 (2.2)	0.719
Hematoma, *n* (%)	15 (2.7)	10 (2)	0.444
SSOPI, *n* (%)	14 (2.6)	5 (1)	0.061
Recurrence, *n* (%)	16 (2.9)	4 (0.8)	**0.013**

Values in bold represent a p value < 0.05

CCI® Comprehensive complication index, *SSEs* surgical site events, *SSI* surgical site infection, *SSOs* surgical site occurrences, *SSOPI* surgical site occurrence procedural intervention

Discussion

This study compared 606 L-TEP repairs with 547 R-TAPP repairs. Notable preoperative differences include a higher proportion of ASA-II and ASA-III patients and complex inguinal hernias in the RIHR group. These patient and hernia characteristics may indicate higher risk repairs in the

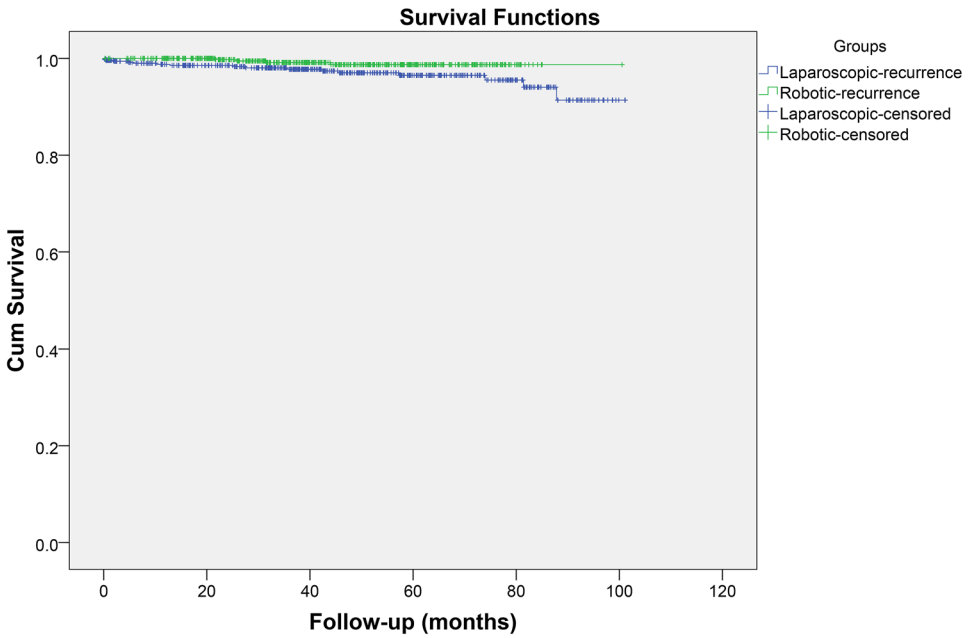

Fig. 1 Kaplan–Meier's time-to-event analysis showing estimated recurrence-free time

RIHR group. As expected, RIHR procedures took longer to complete on average compared to LIHR (53 vs. 42 min, $p < 0.001$). In the LIHR group, however, a significantly higher number of peritoneal breaches (23 vs. 2, $p < 0.001$) and consequently conversions to other procedures (17 vs. 1, $p < 0.001$) was observed. The TEP approach, although robust and effective, involves a constrained working space, which may increase the chances of inadvertent peritoneal breaches. While these tears are largely benign and can be addressed with simple closure in R-TAPP, they can prove difficult to troubleshoot and may further limit working space during L-TEP. This could explain the higher rate of conversion observed with the LIHR group. Postoperatively, notable outcomes of difference include a higher rate of CD grade IIIB complications (18 vs. 5, $p = 0.012$), the vast majority of which consisted of recurrences (16 vs. 4, $p = 0.013$) in the LIHR group.

In an elegantly designed study, LeBlanc et al. [9] conducted a prospective multicenter pairwise analysis of robotic with open and laparoscopic IHR. One arm of the study involved a propensity score match of 80 L-TEP and 80 R-TAPP repairs. Overall operative times were in favor of LIHR (65 vs. 83 min, $p < 0.001$). The authors comment that this difference may have been influenced by the mesh fixation method; tacks were used in 70.2% of LIHR repairs compared to 2.6% of RIHR repairs ($p < 0.0001$). Moreover, the largest difference in operative time occurs between bilateral repairs, which highlights an important technical difference between these two techniques, whereby bilateral dissection is performed in all L-TEP repairs compared to only in bilateral repairs for R-TAPP. In terms of postoperative outcomes, the only difference observed between the two study groups was a higher number of patients requiring prescription pain medications in the LIHR group (65.4% vs. 45.3%, $p = 0.013$). However, this did not translate to differences in time to return to work nor quality of life as assessed by the Carolinas comfort scale.

Another landmark study comparing these two approaches is Prabhu et al.'s [10] randomized controlled trial (RCT) involving 54 LIHR and 48 RIHR procedures performed with the TAPP technique. This trial showed a longer operative time (75.5 vs. 40.5 min, $p < 0.01$), higher cost ($3258 vs. $1421, $p < 0.01$), and increased surgeon frustration with the RIHR approach. Notably, this study involved unilateral repairs with no prior posterior mesh placement and patients without a history of open lower abdominal surgery. This subset of more complex inguinal hernias may be an area where the robotic platform proves advantageous, with features, including enhanced visualization, precise dissection, and improved surgeon ergonomics [11]. Dedicated comparisons between RIHR and LIHR in complex inguinal hernia repair are currently lacking in the literature. Furthermore, all participating surgeons in the RCT had performed at least 25 robotic and 25 laparoscopic repairs. As the authors point out, the learning curve of both LIHR and RIHR is not well defined and warrants further discussion.

Studies suggest stabilization of operative time with LIHR to occur anywhere between 18 and 75 cases [12–15]. On the other hand, 43–138 cases have been reported for the RIHR learning curve [8, 16]. The heterogeneity of this data may point to the variety in inguinal hernia as a disease process, as well as the differences between surgeons in terms of background, training, knowledge, and operative team. It has also been proposed that robotic technology allows surgeons

to extend the benefits of an MIS approach to patients that they would have otherwise offered an open repair. Interestingly, this phenomenon was observed in Vossler et al.'s [4] study evaluating the predictors of RIHR versus LIHR. They found that surgeons performing a lower number of IHR annually were more likely to attempt RIHR. At face value, the propagation of MIS through robotics may seem promising; however, recent studies have alluded to a degree of skill transference between laparoscopy and robotics [17], which may be an overlooked aspect of a surgeon's learning curve in minimally invasive IHR.

In addition to the selective bias associated with this study's retrospective design, additional limitations include the lack of several variables of interest, such as defect size and cost. As this is a retrospective evaluation, there was no routine follow-up imaging for all patients, and we were unable to track patients for recurrences beyond their final follow-up visit or those who may have had a recurrence and did not follow-up in clinic. Additionally, based on the available literature, we expect to see a significantly higher cost associated with RIHR, which may be an important factor to consider when choosing between RIHR and LIHR. Given the heterogeneity of the data in the literature and of inguinal hernia as a disease process, it remains unknown whether potential reductions in complications and/or recurrences in RIHR can offset its increased cost. Another limitation of this study is that selection criteria for several variables such as type of repair, type of mesh, and method of fixation were not clearly defined, as this was at the discretion of each surgeon, based on their familiarity with the surgical technique as well as the patient and hernia characteristics. Additionally, each surgeon is expected to have undergone a unique learning curve with their chosen approach, making it difficult to account for this confounder. Long term and patient reported outcomes such as quality of life metrics are also lacking and are important measures of repair quality.

This study confirms published literature showing longer operative time with RIHR compared to LIHR. Despite a higher proportion of complex inguinal hernias in the robotic group, however, these repairs saw a lower conversion rate and lower recurrence. The choice of optimal repair may be influenced by factors outside the scope of this study and should always be based upon surgeon skillset matched with patient and hernia characteristics.

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Declarations

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Ethical approval The database used for this study was approved by the Institutional Review Board.

Research involving human and animal rights All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

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